Device for controlling fault currents in a rotating electric machine

The present invention relates to a device for controlling fault currents in the end winding region of the stator in a rotating high-voltage electric machine.

The type of machines under consideration may, for instance, be synchronous machines, asynchronous machines, dual-fed machines, outerpole machines and synchronous flow machines. The machines are in the first place intended to be used as generators in power stations for generating electric power. The machines are intended to be used at high voltages, a typical operating range being voltages from 36 kV up to 800 kV, for instance, so that they can be connected directly to all types of high-voltage power networks. The machines uses high-voltage insulated electric conductors for the stator winding, in the following called winding cables, with solid insulation similar to cables for transferring electric power, e.g. XLPE - cables. The cable is also provided with an outer semi-conducting layer with the help of which its outer potential is defined. The high voltage cables thus enclose the electrical field within the windings. Such an insulated conductor or cable is flexible and it is of a kind which is described more in detail in the PCT applications SE97/00874 and SE97/00875. Additional descriptions of the concerned insulated conductor or cable can be found in the PCT applications SE 97/009001, SE 97/00902 and SE97/00903.

In the event of an internal fault, an electric arc may occur in the machine, which normally finds its way from the position of the fault to other cables or to the stator laminations. In high-voltage electric machines designed for connection to high-voltage power networks without intermediate transformers, these fault currents may be very high. This is due to that the contribution of the short circuit power from the power network can be high. In conventional machines of this type according to the state of the art, which have to be connected to a power network via an intermediate transformer, the contribution to the fault current coming from the network is reduced due to the transformer. However, the short-circuit current contribution from the machine itself may of course be high. In the case of directly connected machines of the type to which the invention relates, the resulting fault currents due to an internal short circuit may be very high. The short-circuit power in this case will be composed of both contributions from the power network and the short-circuit power from the machine itself. It is therefore important that the

high fault current which can occur in directly connected high-voltage machines is controlled so that the damage is as slight as possible.

The object of the present invention is therefore to provide a device in the end winding region, which enables such control of fault currents.

This is achieved by having a device of electrically conducting material connected to ground potential, at the end winding..

By having a device of conducting material in the end winding region , connected to ground , an arc arising in the event of a fault is directed to ground. Thereby the arc does not pass to other cables in the vicinity or to the stator laminations. With a device according to the invention, therefore, an arc occurring in the event of a fault will burn between the position of the fault and ground via this conducting material, thereby minimizing the damage.

In the end winding region of a conventional machines, according to prior art, and typically intended for voltages below 30 kV, it is not possible to insert any non insulated conductive material due to the strong electric fields. In the above mentioned high-voltage machine, the electric field in the end winding region is reduced to zero or close to zero, due to the grounded outer semi-conducting layers of the cables constituting the windings, thereby making fault current control possible.

Arcs occurring in the event of a fault are detected by measuring the current or its derivatives in the phases, for instance, by electronics being provided to disconnect the machine if the current becomes too high or/and if the derivative becomes too large. Another type of fault detection is based on comparing incoming and outgoing currents and, if the difference between them is sufficiently great, this is taken as an indication that a fault exists. Arc monitors in the form of optical detectors are also used.

According to a preferred embodiment of the device according to the invention, the conducting material can be a rod, pipe or the like with a diameter chosen to be as small as possible in order to minimize eddy-current losses, but sufficiently large enough to enable fault currents to be deflected during fault conditions.

According to a second advantageous embodiment of the device according to the invention, the rods or the pipes are placed so close together in the end winding region that electric arcs in the event of an internal fault are safely directed to ground, i.e. an arc occurring in the event of an internal fault is safely caught by the fault-current control device before it finds its way to other cables or the stator lamination.

According to yet another advantageous embodiment of the device according to the invention, the rods or the pipes are inserted a certain distance into the end winding region, this distance being limited so that eddy currents produced in the rods or the pipes are below a predetermined magnitude.

According to still another advantageous embodiment of the device according to the invention, the rods or the pipes are slotted in order to reduce eddy-current losses.

According to yet another advantageous embodiment of the device according to the invention, the rods or the pipes comprise a plurality of rods or pipes of small diameter combined to a bundle having sufficient cross-sectional area to deflect short-circuiting currents arising in the end winding region in the event of a fault.

According to still another advantageous embodiment of the device according to the invention, the rods or the pipes are arranged to be in contact with spacers made of resilient, electrically conducting material, said spacers being applied between adjacent winding cables in the end winding region, in contact with the semi-conducting layers of the winding cables. The rods or the pipes may hereby be inserted into the spacers or into lugs provided on the spacers and each rod or pipe may be arranged to be in contact with several spacers arranged one after the other in the direction of the stator end. In this way the cables in the end winding region part are grounded via the fault-current control rods or pipes which are designed to be able to deflect considerable fault currents.

According to yet another advantageous embodiment of the device according to the invention, the rods, pipes or the like are also used to mechanically stabilize the end winding.

With the device according to the invention, an arc due to an internal fault in the end winding region will be directed to ground via a fault-current control device. The damage to the end winding region is thus reduced.

Embodiments of the invention will now be described in more detail by way of examples only, with particular reference to the accompanying drawings in which;

Figure 1 shows a part of the stator, partially cut away and with the rotor removed,

Figure 2 shows a part of the end winding region with rods inserted for fault current control,

Figure 3 shows a part of the end winding region seen from "inside" the end winding , with spacers between the cables grounded by means of the fault-current control rods,

Figures 4 and 5 shows a detail of the end winding region in Figure 3 on a larger scale.

Figure 6 shows the arrangement in Figures 4 and 5 grounded through a fault-current control rod, and

Figures 7, 8 and 9 are views corresponding to Figures 4, 5 and 6, respectively, showing an alternative embodiment of the spacers between the cables.

Figure 1 thus shows a part of the stator 2 in a rotating high-voltage electric machine. The stator 2 is partially cut away and the rotor removed for greater clarity. The stator winding cables are placed in radial slots 8 in the stator core. The slots 8 extend to the rear section 4 of the stator core.

Figure 2 shows a part of the upper end winding region of the stator as shown in Figure 1 with fault-current control rods inserted between the cables 12 in the end

winding region. The fault-current control rods 10 in the figure, are inserted from above, ending a certain distance from the lamination upper surface 13.

The rods 10 are grounded and the conductors 14 are designed to connect several rods, at 16 ... 18, to a group of rods 10. The rods 10 are placed so close together in the end winding that an arc in is safely directed to ground via the rods 10 and conductor 14 without finding its way to other cables 12 or to the stator lamination, which would otherwise be damaged. The conductor 14 is preferably made of copper or aluminium.

Each fault-current control rod 10 suitably comprises a plurality of rods of small diameter, e.g. 3 mm, combined in to a bundle of rods having sufficient cross-sectional area, e.g. 100 mm^2, to deflect short-circuit currents appearing in the end winding region in the event of a fault. The eddy-current losses are thus reduced.

Figure 3 shows a part of the end winding region from "inside" the end winding, with spacers 20 arranged between adjacent cables 12. The arrangement of these spacers 20, known from patent application entitled "Device at the end winding region in a rotating electric machine", is shown in more detail in Figures 4 and 5. Adjacent cables 12 are thus clamped together (not shown in detail in the figures) with an intermediate spacer 20 of a resilient, electrically conducting material.

The cables 12 consist of a conducting core 22, surrounded by a semi-conducting layer 24, a solid insulation 26 and an outer semi-conducting layer 28 in contact with the spacers 20, as can be seen in Figure 4. The outer semi-conducting layers 28 of the cables 12 are thus electrically connected to each other through intermediate spacers 20. A protruding lug 30 with a hole 32 running through it, is provided at the side of the spacers 20. A fault-current control rod 10 is inserted through the hole 32 in the lug 30 and connected to ground via the conductor 14, see Figures 3 and 6. The semi-conducting outer layers 28 of the cables 12 are therefore grounded via spacers 20, fault-current control rods 10 and the ground conductor 14. As can be seen in Figures 3 and 6, each conductor 14 is connected to a plurality of fault-current control rods, illustrated at 16...18 in a group of rods.

Figures 7, 8 and 9 show views corresponding to those in Figures 4, 5 and 6, respectively, of an alternative embodiment of the spacer 34 with an elongated lug

or flange 36 which, unlike the lug 30 in Figures 4-6, extends along the entire length of the spacer 34. A hole 38 runs through this flange 36, in which a fault-current control rod 10 is inserted via the conductor 14 which combines several fault-current control rods, at 16...18, in to a group of rods, connected to ground.

The ground potential is normally defined by the outer casing of the machine.